Model S508
MGA for Genie-2000

User's Manual

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ISO 9001
SYSTEM
CERTIFIED

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The information in this manual describes the product as accurately as possible, but is subject to change without notice.

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1. Introduction

This document describes how to install and operate Multigroup Analysis (MGA) application in the Genie-2000 environment. One other document by the author of this software is available from Canberra on request.[1]

The MGA application analyzes the Ge spectra of plutonium samples, and reports the relative abundances of the plutonium isotopes and other actinides in the sample. Normal gamma spectroscopy analysis requires a spectrum to be energy and efficiency calibrated before analysis, and sequentially calls several analysis "engines" to perform the analysis. MGA only requires that the spectra be energy calibrated, and it performs its entire analysis in one step.

The MGA application has three operating modes: single low energy detector mode, single high energy detector mode, and two detector mode (where two detectors measure separate spectrums of the same sample).

1. Gunnink, R. (1990). *MGA: A Gamma-Ray Spectrum Analysis Code for Determining Plutonium Abundances*. Report UCRL-LR-103220, Volume 1: Methods and Algorithms. Livermore, California: Lawrence Livermore Nation Laboratory.

2. Installation

To install MGA on your computer, open a Windows 95/NT DOS Prompt window, insert the installation disk into a floppy drive and type:

```
x:\setup
```

where “x” is the drive designator.

3. Operation

When using the Gamma Acquisition and Analysis interactive mode, the datasource to be analyzed is specified with the **File | Open datasource…** menu option. When using the batch environment (page 8), the datasource(s) to be analyzed must be specified in the command.

In the batch mode, a single datasource will be treated as a low energy datasource unless the /HEONLY qualifier (described on page 9) is specified. If a second datasource is specified, the first datasource must be the low energy datasource and the second must be the high energy datasource.

If the datasource(s) have not been initialized for MGA parameters, the defaults (shown in Appendix A, MGA Input Parameters) are assumed. Otherwise, the parameter values in the datasources are used.

To ensure that the analysis algorithms work correctly when MGA is analyzing the low energy plutonium spectrum, the 59 keV and 208 keV peaks (emitted by all plutonium samples) should be present. If the 59 keV peak is missing, the program automatically attempts to find a 129 keV line to use in the calculations. If the 129 keV and 208 keV lines are not found (do not exceed the uncertainty threshold), the low energy spectrum cannot be analyzed. If the marker peaks of the low energy spectrum are not found and the program is operated in a two detector mode, no analysis results are produced for either spectrum.

To ensure that the analysis algorithms work correctly when MGA is analyzing the high energy plutonium spectrum, the 208 keV and 414 keV peaks (emitted by all plutonium samples) must both be present. If either line is missing (does not exceed its uncertainty threshold), the high energy spectrum cannot be analyzed. In the single high energy only mode, no results will be produced at all. In the two detector mode, MGA analyzes only the low energy spectrum, and exits with an error code indicating that the high energy spectrum could not be analyzed because the key line was missing.

In batch mode and in the Interactive Mode, run the general purpose report program (after executing MGA) to produce the desired report. In the Interactive Mode, you can also use the “Generate Report” check box to produce the desired report. Appendix B, MGA Output Parameters, shows the parameters written out as a result of an MGA analysis. Appendix C, MGA Report Output Example, shows an example of the MGA report format.

The **REPORT** program’s standard syntax allows you to specify the report template file name and section, where to direct the report, and so on. Refer to the “Report Template Files” in the Genie-2000 *Customization Tools Manual* for details.

Restrictions

The MGA program for Windows 95/NT requires that the Model S500, Model 502, or Model 504 Genie-2000 Basic Spectroscopy software be already installed on your computer.

The MGA application is designed to analyze only 4096 channel spectra when operating in the two detector mode (both spectra must be 4K). In the single low energy detector mode, the sole spectrum can be either 4K or 8K. If the first spectrum is 8K and a second spectrum is also provided, the program analyzes the first spectrum normally, but exits with a return code indicating that the second spectrum was ignored.

The energy calibration gain setting in the single low energy detector mode must be approximately 0.075 keV/channel. In the two detector mode, the low energy spectrum gain setting should equal the single spectrum in the single detector mode, and the high energy spectrum gain setting must be approximately 0.25 keV/channel. In the single high energy only mode, the gain setting must also be about 0.25 keV/channel. For both spectra, slight deviations from the recommended gain settings will not adversely effect the mathematical algorithms. However, large deviations from the nominal values may cause unpredictable results.

A telescope configuration (where the low energy detector is inside the high energy detector) for the two detector mode is not automatically detected. However, a setup parameter (ACQDETDEPTH, see Appendix A, *MGA Input Parameters*) to indicate a telescope configuration is provided.

If the spectrum file (datasource) being analyzed contains previous analysis results from a general purpose Gamma Analysis and Acquisition (peak search and nuclide identification results), MGA does *not* overwrite them. However, any previous MGA results are automatically overwritten without warning.

This version of MGA supports only the CAM file format. Any other formats must be converted to the CAM format with the FILECNVT batch command (refer to the *Genie-2000 Customization Tools*, Chapter 3, “Batch Procedure Reference”). No graphic output of the fits to the screen is supported.

MGA is available as a batch command or as a Gamma Analysis and Acquisition algorithm. On-line help is available through the **/HELP** qualifier (help text information is provided in “Batch Use of MGA” on page 8).

Interactive Use of MGA

MGA can be selected from the Analyze menu item in the Gamma Acquisition and Analysis window. To use MGA from within the Gamma Acquisition and Analysis window:

1. Open a datasource.

2. Select Analyze from the Gamma Acquisition and Analysis' menu bar to see the list of analysis phases.

3. Select MGA from the MGA/MGA menu item.

You'll see the setup screen in Figure 1.

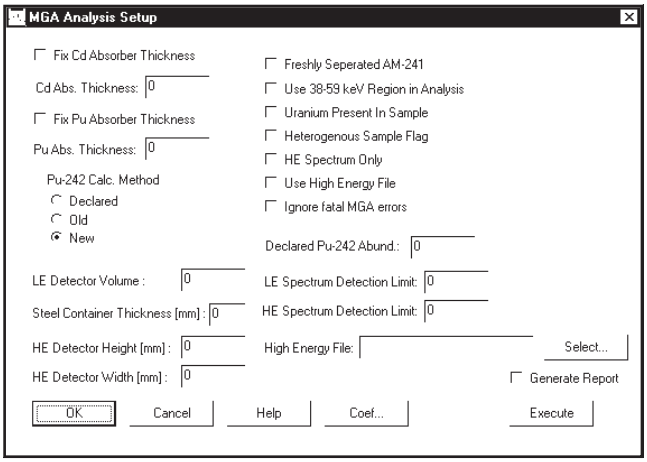


Figure 1 MGA Analysis Setup Dialog

When all parameters, discussed on the following pages, have been set, press the Execute button to start the analysis.

The "Fix Cd Absorber Thickness" check box may be checked to assist the calculations when the statistics are very poor. Normally the Cd thickness is determined from the data. However, with poor statistics, the program may have difficulties making that determination. If the Cd absorber thickness is known, enabling this option usually helps the calculations.

If the "Fix Cd Absorber Thickness" check box is checked, the thickness must be entered in the "Cd Abs. Thickness:" entry field in mm. Otherwise this entry field can be left at zero.

For situations when the plutonium material is not infinitely thick, the calculations may have trouble determining the amount of self-attenuation caused by the plutonium in the sample, particularly if the spectrum statistics are poor. Checking the check box labeled “Fix Pu Absorber Thickness” permits fixing the plutonium thickness to a known value (to be entered in the entry box next to the label “Pu Abs. Thickness”) to assist the calculations.

The Pu-242 calculation method can be selected to be either declared (known), old, or new. If the Pu-242 calculation method is selected to be declared, the appropriate value must be entered in the entry box labeled “Declared Pu-242 Abund.”.

The old and new Pu-242 calculation methods perform the Pu-242 calculations as explained in the MGA report.

When the “New” Pu-242 calculation method has been selected, you may also enter your own Pu-242 calculation coefficients by pressing the **Coef** button. These user-specified Pu-242 coefficients use the following equations to calculate the Pu-242 abundance.

The “ratio” form is given by:

$$[242/239] = C1\,[238/239]^{C2}\;[240/239]^{C3} \\ [(241+Am)/239]^{C4} + C5\,[238/239]^{C8} \\ + C6\,[240/239]^{C9} + C7\,[(241+Am)/239^{\,C10}$$

where sum = 0.01 [238+239+240+241+Am]

where the quantities in [brackets] are the wt percentages and

%Pu-242 = %Pu239 x [242/239]

The “% abundance” form is given by:

$$\%\ Pu\text{-}242 = C1\,[238/sum]C2\,[239/sum]^{C3}\,[240/sum]^{C4}\,[(241+Am)/sum]^{C5}$$

where sum = 0.01 [238 + 239 + 240 + 241 + Am]

The code will automatically detect which form is being used even if only coefficients C1-C5 are non-zero.

Use of the check boxes labeled “Freshly Separated Am-241”, ”Use 38-59 keV Region in Analysis”, and “Uranium Present in Sample” is optional. In nearly all situations, the program detects these conditions automatically.

The “Heterogeneous Sample Flag” refers to how the Am-241 is distributed in the sample. The Am-241 content can be approximated even for heterogeneous material distributions by using this check box in connection with a high energy file.

The “HE Spectrum Only” check box must be checked to analyze a spectrum in the single high energy only mode.

The “Use High Energy File” check box must be checked if a dual detector system is used. When used, the name of the high energy file (with the entire path name) must be entered into the entry box labeled “High Energy File”. Note that you may have a high energy file name in the entry box already. It will not be used unless the check box is checked. Note also that the high energy file name may be selected from a usual file open dialog by pressing the Select button.

The “Ignore fatal MGA errors” is intended to be used in connection with analysis sequences. If checked, an analysis sequence will continue with the next step in the sequence even if the MGA analysis ends in an error.

Check the “Generate Report” button to obtain the default report on the screen.

LE spectrum limit allows the user to specify the low energy spectrum detection limit criteria (maximum uncertainty percent in the 129 and 208 keV peaks). The default value is 30.

The spectrum limit allows the user to specify the high energy spectrum detection limit criteria (maximum uncertainty percent in the 208 and 414 keV peaks). The default value is 10.

The LE detector value entry is optional. The program manually calculates the detector volume starting with a default amplifier of five. For poor statistics and marginal resolution, it often helps the calculations to enter the real detector value (in cm^3).

The steel container thickness (in mm) can be entered if known. This helps calculations when the statistics are poor and the program has problems converging on a solution. Normally, this value is determined directly from the data.

The HE detector height and width can be used to assist the high energy spectrum analysis when the statistics are poor. Normally, the program determines the size of the high energy detector from the data directly.

MGA Report

To see the report, choose Reporting… from the list of Manual analysis phases, then select the MGA.TPL template and the MGA section.

Batch Use of MGA

The following syntax is used for the MGA batch command

Command Syntax

MGA <low energy datasource> [<high energy datasource>][/Qualifiers]

The <low energy datasource> name is required.

Qualifiers

[/ID=<description>]

Specifies a sample identification text string. Up to 16 characters in quotes are allowed for this parameter. The information is stored in the datasource as the parameter SIDENT (sample identification). If this qualifier is omitted, the existing spectrum id remains unchanged.

[/DECL=<declaration date>]

Specifies the declaration date to which the reported activities are decay corrected. This qualifier uses the parameter STIME. If this qualifier is omitted, the acquisition start date/time is written into the STIME parameter (no decay correction). The time syntax must be the same syntax currently defined for the operating system.

[/PU242=<value>]

Specifies the Pu-242 percent abundance in the sample on the *declared* date, if a declared date is given with the /DECL qualifier. If this qualifier is used without the **/DECL** qualifier, the given Pu-242 percent abundance is assumed to be the abundance at the acquisition start time.

If this qualifier is omitted, MGA estimates the Pu-242 percent abundance at the declared time (if a declared date was provided, or else at the acquisition start time) using the results from the other plutonium isotopes.

The Pu-242 percent abundance is written to its own variable name (RELABN in the Pu-242 record). The program also sets a value for a flag parameter, which indicates whether the Pu-242 percent abundance parameter is an entered value or a calculated value.

If the qualifier is assigned a value of –1, the old Pu-242 calculation method is used.

[/SEPTIME=<value>]

Specifies the reactor discharge to chemical separation time (in years). This qualifier is only useful in connection with the old Pu-242 calculation method, and is ignored

if used without it. If the /PU242 = –1 qualifier is used without this qualifier, the separation time defaults to five years.

[/LEDETLIM=<value>]

Specifies the low energy spectrum detection limit criterion (maximum percent uncertainty allowed) in either mode. This qualifier uses the parameter PRMGALEDETLM. If this qualifier is omitted, the value in the file is used. For files where the MGA parameters have not been initialized, a default value of 30 is used.

[/HEDETLIM=<value>]

Specifies the high energy spectrum detection limit criterion (maximum percent uncertainty allowed) in the two detector mode. This qualifier uses the parameter PRMGAHEDETLM. If this qualifier is omitted, the value in the file is used. For files where the MGA parameters have not been initialized, a default value of 10 is used.

[/HEONLY]

Specifies that the current spectrum is a high energy spectrum. If this qualifier is not specified, the current spectrum must be low energy.

[/HELP]

Displays help text for this command.

A. MGA Input Parameters

The following parameters from the CAM file control the execution of the program:

PRMGAANALTYP	Type of analysis (8 characters): always set to STD
ECSLOPE	Gain of the spectrum (should be around 0.075 for the low energy spectrum)
ECOFFSET	Energy of the zero channel of the spectrum (energy offset)

Note The high energy spectrum has its own slope and offset.

PRMGAAMHETRO	Am-241 is heterogeneous (1=heterogeneous, 0=homogeneous). This parameter is effective only in the two detector mode. This parameter should be set to 1, if the Am-241 concentration is not homogeneously distributed within the sample.
PRMGAFIXPB	Pb absorber thickness (mm) around sample (to default to zero always)
MGAFCDABS	Fixed cadmium absorber thickness (in g/cm^2)
PRMGAFIXCD	Use fixed cadmium thickness? (Y/N)
MGAFPUABS	Fixed plutonium thickness (in g/cm^2)
PRMGAFIXPU	Use fixed plutonium thickness? (Y/N)
PRMGANSPEC	Number of spectra used (1 or 2)
NDETHIPBTHK	High energy detector Pb thickness (in mm), default = 0.0
NDETHICDTHK	High energy detector Cd thickness (in mm), default = 1.0
NDETCDCF	High energy detector Cd thickness in second gamma path (in mm), default = 0.0. This value should normally be left at zero. Non-zero values only apply to very unusual configurations where two distinct paths exist between the source and the detector.
ACQDETVOL	Approximate volume (cm^3) of small detector
NSPRMGASTEEL	Steel sample container thickness (mm)
ACQDETDEPTH	1st Ge det. depth (mm)(non-zero value indicates a telescope configuration)

NEFFMGAHFRAC	Fraction of sample in 2nd path. This value should normally be zero. Non-zero values only apply to very unusual configurations where two distinct paths exist between the source and the detector.
NSPRMGA242C0	Multiplier constant for Pu-242 calculation.
NSPRMGA242C1	1st coefficient for Pu-242 calculation.
NSPRMGA242C2	2nd coefficient for Pu-242 calculation.
NSPRMGA242C3	3rd coefficient for Pu-242 calculation.
NSPRMGA242C4	4th coefficient for Pu-242 calculation.
NSPRMGA242C5	5th coefficient for Pu-242 calculation.
NSPRMGA242C6	6th coefficient for Pu-242 calculation.
NSPRMGA242C7	7th coefficient for Pu-242 calculation.
NSPRMGA242C8	8th coefficient for Pu-242 calculation.
NSPRMGA242C9	9th coefficient for Pu-242 calculation.
DETNAME	Det label (2 character descriptor for reporting purposes only, defaulted to blank)
ACQDETDIAM	Large detector diameter (in cm)
ACQDETWIDTH	Large detector height (in cm)
MGATOTCOUNTS	Total spectrum counts required in the low energy spectrum for the analysis to proceed (default=2.0E+4).
PRMGALEDETLM	Low energy spectrum (129 and 208 peak) detection limit % uncertainty (default=30). Measurement uncertainties in percent for the 129 or 208 keV peaks must be less than this value for analysis to proceed.
PRMGAHEDETLM	High energy spectrum (208 and 414 peak) detection limit % uncertainty (default=10). Measurement uncertainties in percent for the 208 or 414 keV peaks must be less than this value for analysis to proceed.
MGALONGREP	Long report flag (0, 1, or 2). For settings 1 and 2, it will write intermediate results into a file MGALONG.TMP. An already existing file will automatically be overwritten. Default = 0.

The parameters below are set to the following constant values:

ACQMGAEFSL	MGA efficiency slope (set to zero)

ACQMGAEFCV	MGA efficiency curve (set to zero). Shaping time-constant for first system (set to 2.0). Shaping time-constant for second system (set to 2.0)
PRMGANOABORT	Always return success status except for I/O errors.

B. MGA Output Parameters

The following MGA calculations results are stored in the CAM parameters (parameter names are followed by descriptions).

Common Parameters

MGAVERSION	MGA version information (16 characters)
PUTHICK	Thickness the plutonium sample (in g/cm^2)
CDTHICK	Thickness of the Cadmium absorber (g/cm^2)
QFIT	Regular goodness-of-fit
NQFIT	Intensity normalized goodness-of-fit
FWHM122	FWHM at 122 keV (in eV)
FWHM208	FWHM at 208 keV (in eV)
AMSEPTIME	Time since Am-241 separation (seconds)
DAMSEPTIME	Percent error of time since Am-241 separation
USEPTIME	Time since U-237 separation (seconds)
AMTOPU241	Am/Pu-241 weight ratio
DAMTOPU241	Percent error in Am/Pu-241 weight ratio
UTOPU	U/Pu ratio from fluorescence x-rays
DUTOPU	Percent error in U/Pu ratio from fluorescence x-rays
PU240EFF	Pu-240 effective
DPU240EFF	Percent error of Pu-240 effective
TOTSPOW	Total specific power (mW/g)
TOTCOUNTS	Total number of counts in the low energy spectrum
LEFILENAME	Name of the low energy spectrum file (stripped, 32 characters)
HEFILENAME	Name of the high energy spectrum file (stripped, 32 characters)

HELIVE	Live time of the high energy spectrum (stored into the low energy spectrum file for reporting purposes)
HEREAL	Real time of the high energy spectrum (stored into the low energy spectrum file for reporting purposes)
DTOTSPOW	Uncertainty in total specific power (mW/g)
MGAPU242TYP	Pu-242 calculation method (“Declared”, “New”, “Old”)
U235RECNO	The record number of the U-235 analysis results (makes reporting easier)
NP237RECNO	The record number of the Np-237 analysis results (for reporting)
U238RECNO	The record number of the U-238 analysis results (for reporting)
AM243RECNO	The record number of the AM-243 analysis results (for reporting)
MGAFLAGS	0=no results, 1=MGA analysis done and results exist
AM100ABN	If Am-241 is heterogeneous, the Am-241 abundance relative to Pu-239 is based on the 100 keV region analysis. If Am-241 is homogenous, set to zero.
DAM100ABN	If Am-241 is heterogeneous, the percent Am-241 abundance relative to Pu-239 error is based on the 100 keV region analysis. If Am-241 is homogenous, set to zero.
AM300ABN	If Am-241 is heterogeneous, the Am-241 abundance relative to Pu-239 is based on the 300 keV region analysis. If Am-241 is homogenous, set to zero.
DAM300ABN	If Am-241 is heterogeneous, the percent Am-241 abundance relative to Pu-239 error is based on the 300 keV region analysis. If Am-241 is homogenous, set to zero.
AM600ABN	If Am-241 is heterogeneous, the Am-241 abundance relative to Pu-239 is based on the 600 keV region analysis. If Am-241 is homogenous, set to zero.
DAM600ABN	If Am-241 is heterogeneous, the percent Am-241 abundance relative to Pu-239 error is based on the 600 keV region analysis. If Am-241 is homogenous, set to zero.
PCT100600	If Am-241 is heterogeneous, the percent difference between the Am-241 abundance relative to Pu-239 error is based on the 100 keV region analysis and the 600 keV region analysis. If Am-241 is homogenous, set to zero.

AMSTDDEV	Related to the heterogeneous Am-241 calculation. If Am-241 is homogenous, defaults to zero.
AMBETA	Related to the heterogeneous Am-241 calculation. If Am-241 is homogenous, defaults to zero.
MGAZR95CONC	Zr95 concentration (Bq/g)
MGAZR95CERR	Error in Zr95 concentration (percent)
MGANB95CONC	Nb95 concentration (Bq/g)
MGANB95CERR	Error in Nb95 concentration (percent)
MGARU103CONC	Ru103 concentration (Bq/g)
MGARU103CERR	Error in Ru103 concentration (percent)
MGARU106CONC	Ru106 concentration (Bq/g)
MGARU106CERR	Error in Ru106 concentration (percent)
MGACS137CONC	Cs137 concentration (Bq/g)
MGACS137CERR	Error in Cs137 concentration (percent)
MGACE144CONC	Ce144 concentration (Bq/g)
MGACE144CERR	Error in Ce144 concentration (percent)

Note For all fission products, a concentration error of 100% indicates that the concentration is a 3 sigma upper limit, not an activity actually found.

MGAERR01	Error number 1 (occurred = 1, did not occur = 0)
•	
•	
•	
MGAERR25	Error number 25 (occurred = 1, did not occur = 0)
MGAERRA	Error amplification A (float)
•	
•	
•	
MGAERRJ	Error amplification J (float)

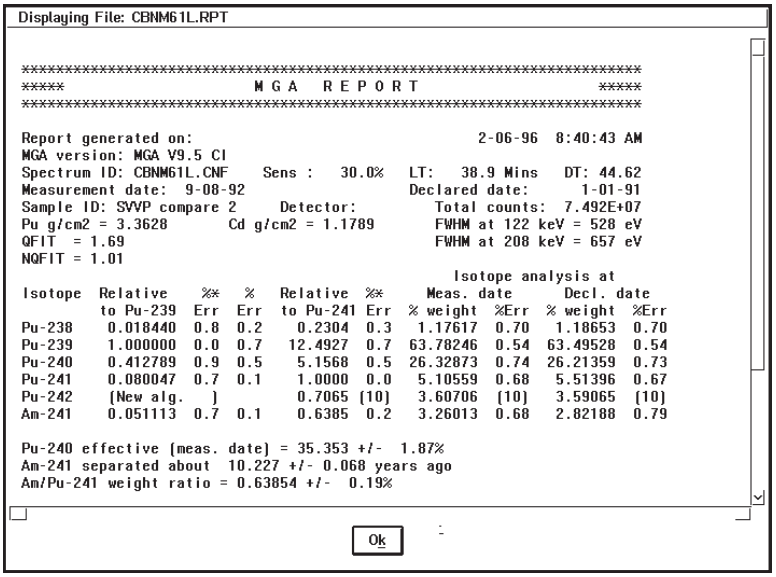
Note Most error messages are handled by the report template because their positions in the error array are fixed.

Record Parameters

VARNAME	Isotope name (e.g. Pu-238, Am-241, etc.)
RELABN	Relative abundance to Pu-239
DRELABN	Percent error in relative abundance to Pu-239
DRELABNR	Percent error in relative abundance ratio
WGTPCTM	Weight percent at measurement time
DWGTPCTM	Percent error in weight at measurement time
WGTPCTD	Weight percent at declaration time
DWGTPCTD	Percent error in weight at declaration time
SPECPWR	Specific power (mW/g)
241RELABN	Relative abundance to Pu-241
241DRELABN	Percent error in relative abundance to Pu-241
241DRELABNR	Percent error in relative abundance ratio
VCVM1-VCVM16	Covariance matrix for the abundance uncertainties (2n+1, where n is the number of isotopes).

The SOLUTION analysis type is disabled.

C. MGA Report Output Example



Displaying File: CBNM61L.RPT

```
**************************************************************************
*****                      M G A   R E P O R T                       *****
**************************************************************************

Report generated on:                                    2-06-96  8:40:43 AM
MGA version: MGA V9.5 CI
Spectrum ID: CBNM61L.CNF    Sens :   30.0%   LT:   38.9 Mins   DT: 44.62
Measurement date:  9-08-92                   Declared date:      1-01-91
Sample ID: SVVP compare 2     Detector:         Total counts:  7.492E+07
Pu g/cm2 = 3.3628       Cd g/cm2 = 1.1789       FWHM at 122 keV = 528 eV
QFIT  = 1.69                                    FWHM at 208 keV = 657 eV
NQFIT = 1.01
                                                  Isotope analysis at
Isotope  Relative    %*   %   Relative  %*     Meas. date      Decl. date
         to Pu-239  Err  Err  to Pu-241 Err  % weight  %Err  % weight  %Err
Pu-238    0.018440  0.8  0.2    0.2304  0.3   1.17617  0.70   1.18653  0.70
Pu-239    1.000000  0.0  0.7   12.4927  0.7  63.78246  0.54  63.49528  0.54
Pu-240    0.412789  0.9  0.5    5.1568  0.5  26.32873  0.74  26.21359  0.73
Pu-241    0.080047  0.7  0.1    1.0000  0.0   5.10559  0.68   5.51396  0.67
Pu-242    (New alg.   )         0.7065 (10)   3.60706  (10)   3.59065  (10)
Am-241    0.051113  0.7  0.1    0.6385  0.2   3.26013  0.68   2.82188  0.79

Pu-240 effective (meas. date) = 35.353 +/-  1.87%
Am-241 separated about  10.227 +/- 0.068 years ago
Am/Pu-241 weight ratio = 0.63854 +/-  0.19%
```

Ok

Figure 2 Typical MGA Output Report

D. MGA Error Messages

The MGA program may set several warning flags in the datasource. The following messages, corresponding with MGAERR01 up to MGAERR31, may be listed in the report:

01 “Count rate exceeds x cps.”: The low energy spectrum count rate is higher than x cps. x equals CAM parameter MGAERRB, multiplied with 20000.

02 “Low energy spectrum > 4K: high energy spectrum ignored.”: When the low energy spectrum exceeds 4K, the high energy spectrum will not be considered.

03 “Bad system gain/zero: establish better scaling.”: The positions of one or more peaks are quite different from the positions calculated using the zero/gain values based on the energy calibration. Either the analyzer zero/gain should be adjusted or the spectrum should be recalibrated.

04 “Efficiency curvature was fixed due to low peak areas.”: The efficiency curvature is not allowed to be a free parameter when the peak intensities are too weak. Solution: Get more data.

05 “59 keV peak is weak: use less cadmium absorber.”: A Cd filter is usually used to attenuate the 59 keV peak. A better analysis could be made of the current sample by reducing the filter thickness (if possible) .

06 “59 keV peak is intense: use more cadmium absorber.”: Not enough Cd absorber used. If the count rate can be increased (by better geometry, less collimation, etc.), then a better analysis could perhaps be made of the current sample by increasing the Cd filter thickness.

07 “U-237 - Pu-241 nonequilibrium detected.”: The peak intensities of U-237 and Pu-241 indicate that the two isotopes are not in an equilibrium decay rate.

08 “Lead x-rays observed: Np-237 results could be affected.”: Pb shielding that is not properly covered with Cd will produce Pb x rays. These x rays will compromise the Np-237 results when using a single 4K spectrum. If an 8K, or a second spectrum is used, the Np-237 abundance is calculated from the 312 keV peak of Pa-233.

09 “Lead x-rays observed.”: Pb x-ray peaks observed in low energy spectrum.

10 “High side tailing observed: check pole-zero or count rate.”: The high-sides of the 59 and 208 keV peaks are examined. The message is given if a significant deviation from a Gaussian distribution is found. The Pu-240 result is particularly sensitive to this condition.

11 “Error in GFIT routine: probable weak peak in location x.”: MGA had problems to fit a given region. x represents the location of the weak peak, causing the problem (CAM parameter MGAERRC). This condition is not usually serious, but if it persists, steps should be taken to investigate its cause.

12 “Calculations in MGAABS didn’t converge: results may be suspect.”: One of more parameters in the iterative non-linear least-squares process in subroutine MGAABS did not converge properly. Action was taken to force convergence. The analysis results may have been compromised. Check if the low-energy detector volume specified in the file is approximately correct.

13 “Efficiency curvature boundary reached.”: The change in curvature of the efficiency curve is greater than allowed. Make sure the low-energy detector volume specified in the file is approximately correct.

14 “Efficiency slope too shallow.”: Problems with the efficiency calibration calculations.

15 “Efficiency curvature boundary reached. Efficiency slope too shallow.”: MGA problems with the efficiency calibration calculations.

16 “ADC exhibits significant odd/even effect.”: The “weighted” residuals of the odd- and even-numbered channels in the 100 keV region are summed and compared. The above warning message is given if they are statistically different. The value of QFIT will increase, but the results may not be affected.

17 “Thorium x-rays detected in spectrum.”: MGA found Th x-rays. Very rare condition. Reported for information only.

18 “Pu-241/Pu-239 efficiency changed in MGACAL by x%.”: The efficiency curve in the 125-148 keV region is further evaluated when the sample contains a significant amount of Am-241. A significant change in excess of 1% is reported as warning that the different methods of determining the efficiency slope in this region do not exactly agree. The reason for disagreement should be studied (x equals CAM parameter MGAERRD).

19 “FWHM of the low energy detector > 700 eV.”: MGA noticed resolution problems for the low energy spectrum. The results might be improved with the use of a detector with better resolution.

20 “High FWHM**2 vs. energy slope > x (radiation damage ?).”: MGA had problems to derive the FWHM equation (x equals CAM parameter MGAERRA).

21 “FWHM of the low energy detector > 700 eV.”: MGA noticed resolution problems for the low energy spectrum. The results might be improved with the use of a detector with better resolution.

22 “Poor quality-of-fit: results may be suspect.”: The NQFIT figure of merit exceeds 1.02. The results may still be good, but if the magnitude of NQFIT is significantly high, the residuals should be examined.

The following messages refer to messages coming from the higher energy part of the gamma ray spectrum, which is only analyzed in the 8K and two detector modes.

23 “Coax. detector spectrum not at .25 keV/channel.”: Problems with the energy calibration of the high energy spectrum. It is advised to adjust gain or zero settings. The normal gain for a coaxial detector is approximately 0.25 keV/channel.

24 “208 keV FWHM of coax det. > 1.2 keV: coax. spectrum not used.”: Resolution problems for the high energy spectrum, which is not used any more for further analysis. Better results might be obtained with the help of a better resolution detector.

25 “208 keV resolution exceeds 1.6 keV: coax. spectrum not used.”: Coax detector resolution is unacceptable. Analysis will be based only on the low-energy spectrum.

26 “208 keV peak too weak: high energy spectrum not used.”: The percent error of the 208 keV peak in the coax spectrum exceeded the allowable value given in the file. Analysis will be based only on the low-energy spectrum.

27 “414 keV peak too weak: high energy spectrum not used.”: due to a too weak 414 keV peak, MGA could not derive a good resolution calibration for the high energy spectrum, which is not used any more for further analysis.

28 “630 - 660 keV region too weak to use.”: The net counts in the 630-660 keV region of the coax detector are too low. This region will not be used in the analysis. Therefore, U-238 cannot determined.

29 “Low energy spectrum gain/zero defaulted to 0.075/0.”: A bad gain or zero value is read from the low energy spectrum.

30 “High energy spectrum gain/zero defaulted to 0.25/0.”: A bad gain or zero value is read from the high energy spectrum.

31 “x MGA parameter(s) defaulted, starting from parameter y.”: x CAM parameters are not initialized or have an illegal value stored in the low energy spectrum (see also INITIALIZATION section). The value y represents the first bad CAM parameter found, according to the input list of the INPUT section, starting from PRMGAFIXPB.

The MGA program may generate the following error messages at execution time:

101 “Input datasource not specified: [0]”: The low energy datasource was not added on the command line

103 “Invalid switch was specified: [0]”: Illegal command line argument was detected

104 “Duplicate switch was specified: [0]”: Same qualifier was entered twice on the command line

106 “Too many switches were specified: [0]”: Too many switches were added on the command line

108 “Invalid switch value specified: [x]”: The program detected an illegal switch value. x can have the next values:

2: bad syntax of declaration date

3: Pu-242 declared value out of range or non-floating point string entered

4: low energy spectrum detection limit value out of range or non-floating point string entered

5: high energy spectrum detection limit value out of range or non-floating point string entered

6: reactor discharge to chemical separation time value out of range or non-floating point string entered.

117 “Error while opening specified input datasource: [x]”: Error during opening of the low or high energy datasource. x equals the type of SAD error

122 “Error during CAM write operation: [x]”: Error when dumping one or more CAM parameters into the low energy datasource. The value of x stands for the next storage phase:

1: reset of MGA results flag MGAFLAGS

2: variable type CAM parameters (MGAVERSION up to MGAPU242TYP of above output list)

3: variable floating point CAM parameters part 1 (PUTHICK up to MGATOTCOUNTS of above output list)

4: variable floating point CAM parameters part 2 (PUXRFINT up to MGATOTSPOW of above output list)

5-9: Pu-xxx analysis results

a: Am-241 analysis results

b: Np-237 analysis results

c: Am-243 (Np-239) analysis results

d: U-235 analysis results

e: U-238 analysis results

f: flag CAM parameters (MGA235REC up to MGATYPE of the output list above)

10: fission isotope concentrations with errors (MGAZR95CONC up to MGACE144CERR of above list)

11: solution analysis results (not stored yet)

12: MGA error message arguments (MGAERRA up to MGAERRF of the above output list)

13: storage of MGAFLAGS (MGADONE set to 1 and MGAERRxx flags).

123 “Error during CAM read operation: [x]”: Error when reading one or more CAM parameter from the low or high energy datasource. The value of x stands for the next input phase:

a: low energy datasource sample information (CAM parameters CHANNELS up to ECOFFSET of above input list)

b: spectral data of low energy datasource

14: high energy datasource sample information (CAM parameters CHANNELS up to ECOFFSET of above input list)

15: spectral data of high energy datasource.

196 “Unable to allocate memory: [x]”: x represents the program phase, where a memory problem occurred:

1: spectral data

2: low energy datasource MGA analysis information

3: high energy datasource MGA analysis information

4: MGA analysis results

5: MGAPC info message data.

197 “Number of channels too high: [x]”: x is 1 for the low energy datasource, and 2 for the high energy datasource.

198 “Invalid parameter value in ”MGA_SETUP": [x]": x stands for the following situations:

0: problem during scanf operation on the string of the environmental parameter MGA_SETUP

y: the value on place y in the MGA_SETUP string is out of range.

Error message 198 will not occur because the environmental parameter is no longer used.

199 “Conflicting declaration and acquisition date: [0]”: Illegal order of the declaration and acquisition date

200 “MGA solution analysis disabled: [0]”: MGA solution analysis type cannot be selected.

201 “Error during access of temporary parameter file: [x]”: A file access error on the temporary file MGAINFO.TMP occurs during the next operation, represented by x:

1: file opening error during info dump by MGA

2: file write error during the dump of low energy datasource analysis information

3: file write error during the dump of high energy datasource analysis information

4: file write error during dump of spectral data

5: file close error during info dump by MGA

6: file opening error during analysis results read by MGA

7: error during analysis results read by MGA

8: file close error during analysis results read by MGA.

202 “Invalid acquisition/sampling date: [x]”: x corresponds with the following dates:

1: low energy datasource sampling date and time

2: low energy datasource acquisition date and time

3: high energy datasource sampling date and time

4: high energy datasource acquisition date and time.

203 “Improper functioning of MGAPC program: [x]” A problem occurred during the execution of the MGAPC program. x reflects the following situations:

1-c4: a program spawning error occurred (for more information see DosExecPgm() return values in the CP reference)

c8: temporary file access error, when MGAPC tried to read the stored information

c9: MGAPC did not store any analysis results in the temporary file

ca: MGAPC did not get any acquisition date and time information

cb: MGAPC did not receive a live time

cc: MGAPC returned an illegal value for one of the error and warning flags.

204 “129 or 208 keV peak too small in low energy spectrum: [x]”: MGAPC could not find one of the indicated calibration peaks. The parameter x represents the following situations:

1: 208 keV peak not found

2: 129 keV peak not found

205 “Number of counts in low energy spectrum too low: [0]”: The low energy datasource does not contain enough counts (bad spectrum)

206 “Matrix is singular: [x]”: MGAPC detected a singular matrix in one of the following Fortran subroutines:

0: in MGAABS

10-25: in MGACAL (empty data entry number, incremented by 9)

110-115: in MGAEQS (number of empty data entry, incremented by 109).

207 “Negative result for Pu-239, Pu-240 or Pu-241: [0]”:

208 “Insufficient counts in 100 keV region: [0]”:

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